MAY, 1909. BOTANICAL SERIES. VOL. II, No. 7.

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

THE VARIETAL CHARACTERS OF INDIAN WHEATS

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AGRICULTURAL RESEARCH INSTITUTE, PUSA
Published for the Imperial Department of Agriculture in India

BY

THACKER, SPINK & CO., CALCUTTA
W. THACKER & CO., 2, CREED LANE, LONDON

PRINTED BY
THACKER, SPINK AND CO., CALCUTTA.

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I. INTRODUCTORY.

During the year 1905, a collection of the wheats grown on the various experimental farms in India was made at Pusa and sown in October of that year. At the same time, a very large set of samples of the wheat actually sown by the cultivators in the districts of the Central Provinces and Bengal was, thanks to the assistance of the Directors of Agriculture and the District Officers of these Provinces, placed at our disposal. An analysis of these samples and of the crops grown in the field in many parts of India during the harvest of 1906, showed that the degree of admixture of totally different types in the wheat fields of India is very great. Further, many of the wheat plots on the experimental farms considered to be pure cultures were in reality mixed, and it became evident that the first condition of wheat improvement in India was the isolation and growth in pure culture of the types already in the country. The importance of this work cannot be overestimated. Pure cultures are necessary for all wheat experiments both for breeding purposes and also for manurial, cultivation and variety trials, for seed distribution and for milling and baking tests. Everything therefore depends on this preliminary work, and until we know with precision

the characters of the wheats now in the country, there is not much point in introducing into India wheats from other parts of the world.

The isolation of pure types from single plants and single ears was commenced at Pusa in 1905 and at Lyallpur in the following year, and has extended over three wheat-growing seasons at both stations. In addition to the work done at these places, we have collected a very large number of wheats from the various Provinces in India and have made extensive tours during the last three wheat seasons. The present paper sums up a large amount of the work so far done on the varietal characters of wheats and the influence of varying conditions on these characters, especially the effect of climate, soil and moisture on the composition and quality of the grain. Attention has also been paid to the milling and baking characters. Another subject of great interest has incidentally been investigated, namely, the frequent occurrence, in the Punjab, of natural cross-fertilisation in the field.

An exhaustive study of the wheats of the Punjab was made at the request of Mr. Renouf, Director of Agriculture of that Province, and the detailed classification of these wheats has been included as an example of the system of classification described in the following pages.

We desire to thank all the officers of the Indian Agricultural Department who have sent us specimens and, in particular, we wish to express our indebtedness to the following: to Mr. F. G. Sly, I.C.S., formerly Officiating Inspector-General of Agriculture in India, to Messrs. Renouf and Dobbs of the Punjab Agricultural Department, and to Messrs. W. H. Moreland, C.I.E., and H. M. Leake of the United Provinces Agricultural Department.

Dr. J. W. Leather, Imperial Agricultural Chemist, has assisted us by making a large number of analyses.

In the milling and baking aspect of the subject we have been fortunate enough to secure the invaluable assistance of Mr. A. E. Humphries, formerly President of the National Association of British and Irish Millers and a well-known authority on these questions.

II.

THE SPECIES AND VARIETIES OF CULTIVATED WHEATS.

The wheats of the world fall into three well-defined species :—

1. *Triticum sativum*, Lam. (= *Triticum vulgare* Vill. in erweitertem Sinne of Koernicke).[1]
2. *Triticum polonicum*, L. Polish wheat.
3. *Triticum monococcum*, L. Einkorn.

The wheats of the whole of the Continent of India, so far as we have been able to ascertain, belong to the first of these three species. These species are well marked and may be distinguished as follows :—

CONSPECTUS OF THE SPECIES.

I. The tooth (Seitenzahn) of the outer glumes blunt, rounded or absent. Pale undivided. Apical spikelet fertile.

1. *T. sativum*, Lam. Outer glumes shorter than the flowering glumes, parchment-like. Pale the same length as the flowering glume.
2. *T. polonicum*, L. Polish wheat. Outer glumes as long or longer than the flowering glumes, papery.

II. The tooth (Seitenzahn) of the outer glumes acute or acuminate, stiff, the ripe pale divided into two halves.

3. *T. monococcum*, L. Einkorn or one-grained wheat.

The first of these three species, *Triticum sativum*, Lam., is subdivided into six sub-species as follows :—

[1] Koernicke, *Die Arten und Varietäten des Getreides*, Berlin, 1885.

TRITICUM SATIVUM LAM.

Ears with a fertile terminal spikelet and brittle or tough rachis. Outer glumes shorter than the flowering glumes with or without a blunt tooth (Seitenzahn). Pales as long as the flowering glumes, undivided.

I. Rachis brittle. Grain enclosed in the glumes when threshed.

1. *Triticum spelta*, L. Spelt. Ears bearded or beardless, long and thin, lax and somewhat square. Outer glumes very broad and truncated with a very short and blunt apex (Mittelzahn) and a somewhat undeveloped keel.

2. *Triticum dicoccum*, Schrk. Emmer. Ears nearly always bearded, dense, broader on the two-rowed side. Outer glumes sharply keeled with an acute apex.

II. Rachis tough. Grains separating from the chaff when threshed.

3. *Triticum compactum*, Host. Dwarf wheats. Ears bearded or beardless, extremely short and very compact, more or less quadrangular. Outer glumes keeled above, rounded below. Straw very short and stiff. Grains rounded.

4. *Triticum turgidum*, L. Rivet wheats. Ears bearded, large and four-sided with the spikelets closely packed on the rachis. Straw very tall, stiff, often solid. Grains large, short and thick with a blunt apex.

5. *Triticum durum*, Desf. Macaroni wheats. Ears large, dense, with long awns. Outer glumes sharply keeled to the base. Straw stiff, usually solid. Grains long, somewhat pointed, hard.

6. *Triticum vulgare*, Vill. Common wheats. Ears bearded or beardless, more or less lax (much laxer than *T. compactum*). Outer glumes keeled above, rounded below. Straw hollow, medium in length. Grains not rounded, more than twice as long as broad.

Only three of the sub-species of *Triticum sativum*, Lam., are represented in the plains, namely, *T. compactum*, Host.; *T. durum*,

Desf.; and *T. vulgare*, Vill.; and the majority of the types, including all those of agricultural importance, fall into the group known as common wheats.

Up to the sub-division of *Triticum sativum*, Lam., into six sub-species, arranged in two groups, most modern botanists are in agreement and the classification of Koernicke in the *Handbuch des Getreide baues* which we have quoted above is the one now in general use. From the point of view of the study of the numerous sorts of wheat in cultivation this classification, however, does not carry us very far. There are a very large number of distinct wheats in each of the six sub-species, and it is necessary to find some means of distinguishing these numerous forms. It is at this point that divergencies are to be met with in the literature[1] on the classification of the cultivated wheats. These differences of opinion arise from the varying degree of importance assigned by investigators to the characters used in separating the types. None of the existing schemes of classification appear to us to be beyond criticism, and we accordingly decided to make a detailed study of the characters of Indian wheats with a view of evolving a method of classification which would combine the botanical and agricultural aspects of the question.

[1] The systems of classification of wheats are dealt with by Eriksson in a paper entitled Beiträge zur Systematik des kultivierten Weizen, *Die landwirtschaftlichen Versuchs-Stationen*, Bd. 45, Heft 1 & 2, 1894.

III.

A CRITICAL STUDY OF THE VARIETAL CHARACTERS OF INDIAN WHEATS.

The influence of the environment on cultivated plants is well known and wheat is no exception to the rule. To a greater or less extent wheat is grown all over India and consequently the conditions, as regards climate, soil and moisture, under which the crop is cultivated, are very variable.

The most important conditions influencing the growth of wheat in India are :—

1. The maximum duration of the growth period in each tract.
2. The available soil moisture during that period.

The duration of the growth period is strictly limited and depends on the time when the hot weather begins in the spring. This varies with the latitude, being earlier in Bombay, the Central Provinces and Behar, a little later in the United Provinces and still later in the Punjab and North-West Frontier Province. As soon as the temperature rises above a certain point and the hot winds begin to blow, the wheat crop ripens off very quickly and dries up if not fully developed by that time. In general the crop may be said to ripen under a rapidly ascending temperature. Harvest takes place in Bombay and the Central Provinces in February, in Behar and Oudh in March and in the Punjab from the last week of April to the end of May. Only rapidly maturing wheats are of use in India either for purposes of cultivation or use in hybridisation.

Of more importance than the growth period is the variation from year to year in the available moisture. Wheat is grown on natural rainfall alone, on excessive canal irrigation as in the canal

colonies of the Punjab, on inundation water from the previous summer, on limited irrigation as in the well-irrigated tracts of the United Provinces, and finally, by means of both natural rainfall and irrigation. The great variation both in the amount and manner in which the water is supplied to the soil produces well-marked differences in the wheat crop both in the external characters such as length and strength of straw and to a greater extent in those characters connected with the quality of wheat such as the consistency of the grain and the brightness of the sample.

Accidental variations in the season have a great influence on the wheat crop in India. Among these may be mentioned excessive wet and cloudy weather just before ripening begins, leading to severe rust epidemics and exceptionally early hot spells leading to loss of soil moisture and consequent loss of maturity. Frost at the period when the grain is coming into ear is not unknown. All these vicissitudes have a marked effect on chaff colour, length and density of the ear and on straw characters, and influence the wheat plant much more than the accidents of the season do in Europe. Consequently workers on wheat improvement in India have to deal with a plant which may not reach its fullest development and may not ripen under normal conditions. It appeared, therefore, that a critical study of the various characters of wheat in India was most desirable with a view of determining how far these characters are modified by circumstances and also to decide which are most useful in India in distinguishing the varieties met with in the country. For this purpose during the last three seasons many different kinds of wheat have been grown both at Lyallpur and at Pusa. These two places in geographical position and climate represent the extreme conditions of the Indian plains. At Lyallpur, the cold weather is long and (for India) intense and the wheat is entirely grown with canal irrigation, the soil being a heavy loam. At Pusa, the cold weather is short, frost is almost unknown and wheats are grown on natural rainfall, the soil being a highly calcareous loam. At Lyallpur the air is in general very dry, whereas at Pusa in January and February the atmosphere is often damp and heavy dews and mists are frequent.

1. The presence or absence of awns.

The character used by almost all botanists from Linnaeus onwards as the first in order of importance in distinguishing varieties of wheat is the presence or absence of awns. As was to be supposed (with the exception of a few cases such as those mentioned below) the amount of bearding or its absence is constant in India and the presence or absence of awns is an important botanical character.

In our pure cultures of Punjab wheats at Lyallpur, which were started from single ears in 1906 and in other similar pure cultures at Pusa we have found that the amount of bearding and also the entirely beardless condition are not absolutely constant but that some variation takes place. Occasionally, in the so-called "beardless wheats," individuals with a certain amount of bearding may be found. In the Punjab wheat known as the Buggi of Leiah two types of ear were observed in the harvest of 1906 which only differed in one respect, one type being quite beardless, the other slightly bearded. These were sown from single ears at Lyallpur and Pusa in 1906 and again in 1907. The produce of both sets of ears was similar and each plot contained both beardless and slightly bearded ears. Often on single plants representatives of both could be found. The beardless and slightly bearded forms appear to be merely examples of fluctuating variability.

In bearded varieties a similar variation is to be met with. In the Punjab types 4 and 9 ears are often seen but slightly bearded. In pure cultures of macaroni wheats, *e.g.*, in the hard grey of Bengal *Gangajali* we have sometimes found beardless ears, due to the shedding of the awns. This is often brought about by rust attacks.

It is to the student of genetics that the variations in bearding are of greatest interest. In the study of the inheritance of awns in wheat breeding it has been found by Biffen,[1] Tschermak[2] and others that the beardless condition is a dominant character.

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1 Biffen, *Journal of Agr. Science*, 1905, Vol. I, p. 93.
2 *Die Züchtung der landwirtschaftlichen Kulturpflanzen*, Bd. IV, 1907.

Saunders,[1] however, states that in some cases the F_1 generation is not always beardless, and that in the F_2 generation forms appeared exhibiting every variation between fully bearded and perfectly beardless types. In some of the crosses made at Lyallpur in 1907 between bearded and beardless parents, grown in pure culture from single ears, we found that the F_1 generation was not quite beardless.

As might be expected from the hot and dry climate of India,[2] the wheats of cultivation are usually bearded. These are preferred by the cultivators to beardless wheats, as they do not so readily shed their grain and can, therefore, be left standing at harvest time for some days after they are dead ripe—a practical point of some consequence where labour is scarce and dear at harvest time as in some districts of the Punjab. It is not likely that beardless wheats, will, on this account, be readily taken up by the ryots unless they possess obviously superior qualities to the bearded forms.

2. Chaff characters.

(*a*) *Felted and smooth chaff.*—The chaff of wheat is either felted (covered with fine velvety hairs) or smooth. In fixed types these characters are exceedingly constant even to the degree of hairiness involved. In all our crosses up to the present where one of the parents has been felted, hairy chaff has proved to be a dominant character thereby confirming the previous observations of Tschermak,[3] Biffen[4] and others.

The degree of hairiness of the Indian types varies very greatly. The Punjab macaroni wheats are very densely felted and the hairs are long, whereas the glumes in the common and dwarf wheats are generally sparsely covered with short hairs. Type 9 of the Punjab, a common wheat, resembles, however, the Punjab macaroni wheats

[1] *Report of the third International Conference on Genetics* (1906).
[2] Koernicke, l. c. and Vilmorin, *Les meilleurs Blés*, Paris, 1880.
[3] Tschermak. l. c.
[4] Biffen, l. c.

in the length and density of the hairs on the glumes while the Behar macaroni wheats have only sparse short hairs.

Felted wheats are much commoner in the drier climate of the Punjab than in the damper wheat-growing tracts of the United Provinces, while in Bengal they are very rare. Possibly this rarity may be due to the disadvantage of hairy glumes in these moister tracts. Felted chaff holds water much more than smooth chaff, and therefore affords greater opportunities for infection by rusts. Even in the Punjab the felted wheats are often stained through the growth of mould fungi of the genus *Cladosporium* and *Alternaria*.

(*b*) *Colour of the chaff.*—The usual colour of the chaff of Indian wheats is red or white. In some cases the chaff is greyish white and varieties are met with both in the Punjab and Behar where the chaff is blackish or nearly black.

In the case of red-chaff wheats not only does the depth and tone of redness vary greatly between different types, but there is also a well-marked relation between the ripening season and the amount of redness developed in any one variety. If the weather during ripening is wet and cloudy, the red colour is not produced and real red-chaffed wheats might be then described as having white chaff. Thus, at Pusa in 1906, when the ripening period was especially unfavourable, the two Bengal macaroni wheats, which are really red-chaffed kinds, were considered by us to be white-chaffed macaronis. Even in good years, red-chaffed wheats often develop side shoots with white chaff due to premature ripening. It is only in good seasons, such as the 1906 and 1908 harvest at Lyallpur and in the present year at Pusa, that the full red colour of Indian wheats is developed. In such cases the differences in redness in the various red-chaffed types is most pronounced. While red chaff is a constant character of the variety, great care must be taken, especially in the damper wheat-growing tracts, in India in deciding this character, and it is not safe to say a wheat has white chaff unless the ears are fully and normally developed. In the Punjab one red-chaffed wheat, type 12, often shows a blackish border on the glumes. In

Bengal a form with black chaff occurs, but this black colour is only developed in good seasons.

White-chaffed wheats in India are very different from the white-chaffed varieties of Europe. Most of the Punjab white-chaffed forms have a marked reddish tinge about the glumes and awns, while the glumes have often a distinctly pink edge. A similar reddish tint is observable in the white-chaffed wheats of the United Provinces and Behar. This reddish tinge of the chaff and awns of the white-chaffed wheats combined with the poor development of colour in bad years in red-chaffed wheats makes the determination of chaff colour sometimes most difficult. One of the Punjab wheats, type 9, has greyish white chaff, but this is, no doubt, due to the thick felting on the chaff. In one case in the Punjab, the chaff is distinctly yellowish-white, but in this instance it is probable that the wheat in question was introduced into India from Australia.

Several of the wheats of India have black awns. The development of this black colour, which is seen in types 1, 2 and 9 of the Punjab, varies from year to year and only comes out well in a good year. Even in the best seasons, however, some of the "black-awned wheats" do not develop the black colour in all the ears. In 1906 at Lyallpur several ears belonging to type 1 were isolated which had perfectly white awns and only differed in this respect from ears in which the awns were deep black. The black and white-awned ears were sown singly in 1906 and again in 1907, and gave rise to absolutely similar plots. These observations agree with those of Koernicke[1] who grew the variety black-awned Emmer (*T. dicoccum* var. *atratum*) for eight years in East Prussia and seventeen years at Popplesdorf. It was found that the black colour of the awns was not always developed to the same extent and in one year was entirely absent, the variety simulating in that year the white-eared Emmer (*Triticum dicoccum* var. *majus*). In the following year, however, the awns were blacker than ever.

[1] Koernicke, l. c.

3. Grain characters.

(*a*) *Colour.*—The colour of the matured grains of the Punjab and other Indian wheats we have so far examined is either red or white. The tint of colour of both classes varies a good deal. The red wheats vary from dark brownish-red to light red, while the white wheats include yellowish and amber tints. We have experienced no difficulty in determining the colour except in cases of unripe ears where the red colour is not so well marked. As a general rule, the Indian white wheats exhibit a clearer and more marked white colour than those of colder countries.

While the various red and white wheats show different and often characteristic tints, we have not used these tints to separate the kinds on account of the influence of soil and temperature during the ripening period on the tone of colour. As will be seen in the next section, the particular tone of colour depends partly on the consistency of the grain, and since consistency varies in the same variety, both from year to year in the same locality and also in different localities in the same year, it is not safe to use tone or tint of colour as a distinguishing character. As an example of the change of tone of colour, the cultures from the same sample of Muzaffarnagar white wheat at Muzaffarnagar, Lyallpur and Pusa in 1908 may be quoted. The three samples, when placed side by side, appear quite different. The Muzaffarnagar sample is clean white, the Pusa sample amber, and the Lyallpur one intermediate.

We have been at great pains to obtain reliable evidence on the question of the change of white wheats to red when introduced into fresh localities. There are a large number of loose statements both in the Indian and European literature on this subject, and many observers consider that white wheats change into red ones when grown on certain soils. Thus, Percival[1] states:—"White wheats, however, become red in warm climates or when grown on certain soils, so that this character is of little value in a scientific scheme of classification of the different varieties." Eriksson[2] believes that white wheat

[1] Percival, *Agricultural Botany*, New Edition, 1902, p. 504.

[2] Eriksson, l.c.

becomes red and quotes Werner in support, and even goes to the length of stating that the colour of the grain is useless in distinguishing a variety. In no case, however, have we found that these supposed transformations are based on recorded scientific evidence. It is, of course, often found that when an *ordinary sample* of white wheat is tested in a new locality, the resulting grain in a few years is entirely or almost entirely red. A little consideration, however, will show that this result is no evidence of the change of a white wheat into a red one. White wheats as *ordinarily grown* in Europe and much more so in India are not pure cultures. They generally contain red wheats as impurities and, as a rule, red wheats are hardier than white sorts. Consequently, when a white wheat containing red impurities is grown in a non-white wheat locality, the struggle for existence between the red "weeds" and the white sort which at once begins, may easily result in the gradual victory of the red. In a few years, the white wheat may have disappeared entirely. The result of this alteration from a white to a red sample is of course due to the victory of the red over the white and affords no proof of a change[1] from white to red. We have so far found no evidence in the literature on wheat of a white wheat changing into a red one *when grown in pure culture from a single ear and in land where contamination of the cultures, from stray seeds left from a previous crop or from manure or irrigation water, has been guarded against.*

In seeking to obtain experimental evidence on this point in India, we were fortunate enough in 1906 to obtain a very good example. The white wheat, known as Muzaffarnagar white, has been tested in many parts of India including Oudh and Behar. In the samples grown at Pusa, Cawnpore, Lyallpur and in the Muzaffarnagar district itself, we found that the wheat was not pure but contained among other things a red wheat very similar in the ear to the true Muzaffarnagar white wheat. Pure cultures of these wheats from single ears have been grown at Lyallpur and

[1] See de Vries, *Species and Varieties—their Origin by Mutation*, 2nd Edition, page 99, and Darwin, *The Variation of Animals and Plants under Domestication*, Vol. 1, page 334.

Pusa for the last two years. No change from white to red has yet taken place, but at both stations the red form grows more vigorously than the white, and if grown in competition, there is no doubt that the red sort would win.

In many other pure cultures of both red and white wheats at Lyallpur and Pusa during the last two years, no change of white to red grain or the reverse has been noticed except in cases of natural cross-fertilisation at Lyallpur which will be discussed later on. We accordingly believe that the colour of the grain is a constant character and one of considerable value in systematic work.

In our hybridisation experiments in India we have so far found that red grain is dominant over white, a result previously obtained by many other investigators.

(*b*) *Consistency.*—A large number of observations have been made both in Europe and America on the consistency of wheat. The subject is of great importance on account of the fact that strength is often associated with a hard and translucent endosperm. The general result so far has been to indicate that consistency depends on the soil, on the available moisture and on the nutrition of the crop. Thus, in the United States, Le Clerk[1] states in the case of Durum wheats, that in humid districts and under irrigation the grain tends to become starchy, while in drier localities the grain remains flinty with a higher nitrogen content. Eriksson[2] in Sweden concludes that consistency is of no systematic value and depends more on the season than on the kind of wheat. He found that wheats brought to Sweden from Southern Europe became more and more glassy except in good years. Koernicke[3] at Poppelsdorf found there was often a change from floury grains to flinty and also the reverse, and that these changes depended both on soil and season. Fruwirth[4] in a recent discussion of the subject concludes that consistency varies with the season, soil and nutrition of the crop, and that in Europe wheats become increasingly floury from east to

1 L. Clerk, *Yearbook of the U.S. Department of Agr.*, 1906.

2 Eriksson, l. c.

3 Koernicke, l. c.

4 Fruwirth, l. c.

west and from south to north. Raum[1] at Munich found that the North German and exotic varieties became more and more flinty each year and tended to resemble the flinty Bavarian wheats. The consistency of the exotic kinds was also found to be influenced by season to a much greater extent than that of the local wheats. At Pusa, Leather has found in pot cultures of one of the Bengal macaroni wheats, that the addition of superphosphate and oil cake to the local soil alters the proportion of nitrogen to starch.

Our attention was drawn to this question during the harvest of 1906 in the Punjab. We found that in numerous cases, especially in the so-called soft white wheats, ears could be found which contained soft, hard and spotted grains. Similar observations were made in 1907 and 1908 both at Pusa and Lyallpur, and in the case of numerous samples of ears sent to us from other parts of India. We found in the case of pure culture wheats from single ears that both at Lyallpur and at Pusa soft wheats tend to become flinty. The reverse change from hard to soft is rarer, but is to be met with in macaroni wheats, *e.g.*, Punjab types 1 and 2, and the Bengal durum wheats at Pusa. A very large number of our Punjab white wheats at Lyallpur in 1908 showed hard, soft and spotted grains. There was no question of admixture, as the original selection from one ear in 1906 was made by us as well as all the subsequent sowings and harvestings and the samples were kept in safe custody. Our general experience has been that hard wheats do not change in consistency so easily as soft wheats. Both at Pusa and Lyallpur we have obtained samples differing in consistency from the same variety grown the same year in different fields or on slightly different soils. In 1908, with large cultures of selected Muzaffarnagar wheat, obtained the previous year from Muzaffarnagar, at both Pusa and Lyallpur the grain was more flinty than the original and also gave a higher nitrogen content on analysis. We conclude, therefore, with Eriksson, Koernicke and Fruwirth that consistency is useless as a varietal character and that it depends on the environment. We

[1] Raum, *Zur Kenntnis der morphologischen Veränderungen der Getreidekörner unter dem Einflusse klimatischer Verhältnisse*, Munich, 1906.

further think that it is likely that soft white wheats are only naturally produced in India in certain well-defined localities such as the western districts of the United Provinces, in the Nerbudda valley and in South Behar. Other localities, such as North Behar and Oudh and the Chenab colony of the Punjab, tend to produce more glassy wheats.

(*c*) *Shape.*—The general shape of the grain in the macaroni, dwarf and common wheats of the plains varies greatly and is characteristic of the sub-species. The macaroni wheats are, long berried, Punjab type No. 3, particularly so. Humphries[1] considers that the seeds of this type are too long to be milled in the machinery in use at present in England, and that it would pass over standard sieves with the larger impurities. The dwarf wheats have small rounded grains, especially types 7 and 4. All these dwarf wheats are unsuitable for use in England on account of the fact that the machinery used in extracting the small seeds would simultaneously take out a large proportion of the sample itself. As regards the shape of the grain in the common wheats of the Punjab, no differences of systematic value have been observed.

4. Straw characters.

(*a*) *Strength.*—In the selection of wheat varieties for cultivation, the strength of the straw is of great importance. Weak-strawed forms, however excellent in other respects, are very apt to be laid by rust, rain and wind during the ripening period, a circumstance which greatly diminishes the yield. Among the common wheats of India there are great differences in the strength of straw. Most of the wheats of the United Provinces are particularly weak as regards the straw. In general, there seems to be a connection between the strength of straw and the erectness of the ear—the stronger-strawed forms being those with erect ears at harvest time, while ears of the weaker-strawed forms bend over when ripe. Further observations on this point are desirable.

(*b*) *Structure.*—The distinctive characters of the straw of the sub-species of wheat found in the plains is well maintained. The

[1] See Appendix A.

macaroni wheats have tall straws solid in the upper portion, the other two sub-species have hollow stems. The dwarf wheats, however, have short, stiff and strong straws, while those of the common wheats are taller, thinner and on the whole weaker. No exceptions to the general rule, such as macaroni wheats with hollow stems and common wheats with solid straws, as mentioned by Koernicke,[1] have been noticed.

(*c*) *Length.*—The common wheats have straw intermediate in length between the tall stems of the macaroni wheats and the short straw of the dwarf wheats. There is considerable variation, however, in the length of straw between the various common wheats of the Indian plains.

(*d*) *Colour.*—The colour of the straw may be white, yellow or pink. The pink colour is especially well-developed in some of the Punjab dwarf wheats (types 5 and 7) and in type 19, a common wheat. It is also seen in the two Bengal durum wheats but only in good years. After exposure to the sun or after long storage the colour fades to a dirty greyish tint. It is best seen in the field just before the crop is ripe.

As regards the general straw characters, besides the main differences in the sub-species, the numerous varieties of each sub-species show well-marked straw characters. In some the straw is tall and strong and not liable to lodge and the colour may be pink. Such straw characters, however, are difficult to determine, for the length of the straw as well as its strength depends to a very large extent on the nature of the soil, the nutrition and the soil moisture. Fortunately, the character of the straw is not often needed as the sole means of distinguishing types, but if it has to be used, the wheats must be grown next to next in similar soil and under equal conditions in order that reliance can be placed on such characters. In studying the Punjab wheats, we have found it necessary in one case to separate two agricultural types mainly on their straw characters and also on earliness and lateness. In this case, however, the

[1] Koernicke, l. c.

wheats were grown in pure culture next to next under uniform conditions and were sown at the same time and at the same seed rate. This was done for two years and at each harvest the wheats differed markedly in length and strength of straw and in time of maturity, and we had no doubt that we were dealing with two different agricultural types.

5. Leaf characters.

The leaves of the three sub-species are quite distinct. The macaroni wheats have very large leaves, the dwarf wheats short and erect foliage, while the common wheats are intermediate in this respect. The leaves of the various types differ both in colour and in the degree of hairiness, but these characters were not found necessary for distinguishing the types and were not studied in any great detail. There seemed to be a distinct relationship between the water requirements of some of the sorts and the extent and character of the leaf surface, but we have so far had no opportunity of following out this point. The dwarf wheats appear to be able to mature with little moisture, while the macaroni wheats and also type No. 9 require more water to reach maturity than the other Punjab common wheats. On account of the importance of irrigation in wheat-growing in the Punjab, it appears desirable to work out in detail the water requirements of the various kinds when grown under the conditions of ordinary cultivation.

6. Earliness and lateness.

The relative earliness and lateness of varieties in India is not easy to determine with precision. It is a character which is very apt to be masked by the result of differences in soil moisture. The wheat crop in India is so exceedingly sensitive to small differences in soil moisture that a small change of level in a plot is sufficient to make a considerable difference in the time of ripening. This character must therefore only be used when the varieties are grown next to next in uniform soil and under uniform conditions. In one of our plots of macaroni wheat at Lyallpur in 1908 one-half was quite green while the other half was ripening off, the level of the unripe end

being a little lower and consequently damper than the other. Similarly at Pusa in the same year several sorts were sown in duplicate, one set on somewhat light loam, the other on heavy soil. The difference in the time of ripening of the two sets of plots was about 14 days, that on the lighter soil being of course the earlier. In our three years' study of the Punjab wheats we have always noticed certain broad distinctions in the time of ripening. The macaroni wheats and type 9 are distinctly later than the rest. Two agricultural types of common wheats were distinguished by paying attention to this point among others, but in general we have left the further details connected with this character to be settled when the types are grown on a larger scale. Several years' careful study will be required to decide the relative earliness and lateness of these types with precision. The wide differences in earliness and lateness inherent in the kinds such as are obvious in Europe are not to be seen in India as the shortness of the season renders the cultivation of really late kinds impossible. Even Canadian wheats like Red Fife only form shrivelled seed at Lyallpur while many of the European sorts do little more than come into ear before they are dried up by the hot winds. Some of the kinds, including Einkorn, do not even begin to shoot.

7. Susceptibility to rust.

We have observed the pure culture plots at Lyallpur and Pusa during the last two years with a view of finding rust resistant kinds for use in hybridisation. In dealing with this point it is necessary to realise that rust in India as elsewhere is only a general term and that there are several distinct wheat rusts in India. This aspect of the subject has been dealt with by Butler and Hayman.[1] The only season during the last three years at Lyallpur when the crop was damaged by rust was in 1907 when there was an epidemic of yellow rust (*Puccinia glumarum*, Eriks. and Henn.) and also a certain amount of black rust (*Puccinia graminis*, Pers.). All the 25 types of Punjab wheat were attacked by yellow rust, the only

[1] Butler and Hayman, *Memoirs of the Dept. of Agr. in India*, Botanical Series, Vol. I. No. 2, Calcutta, 1906.

Indian wheats which were resistant being Emmer[1] (*T. dicoccum* Schrk.) In 1906 and 1908 the amount of rust at Lyallpur was slight. Further detailed observations are necessary to work out the relations between the Punjab wheats and the rusts which attack them and the work is now possible as the types have been isolated and grown in pure culture. As in other characters, observations on rust resistance are of no value when the plots are mixtures of many different kinds. Some of the Punjab types have been grown at Pusa when most of them were severely attacked by brown rust (*Puccinia triticina* Eriks.). Both at Pusa and Lyallpur we observed great differences in the amount of rust on the same variety when sown on slightly different soils. At Pusa, there is as a rule much more rust when the soil moisture is liable to give out, than there is on the heavier moisture retaining soils. The degree of susceptibility of the various kinds to the three Indian rusts is of importance in plant breeding as Biffen[2] has found in England that immunity to yellow rust is a recessive character.

8. Structure of the ear.

(*a*) *The form or shape of the ear.*—The shape of the ear of the common wheats of the plains of India does not exhibit the same range as in Europe, and it is not possible to utilise this character to the same extent as has been done at the Svalöf[3] Experiment Station in Sweden.

(*b*) *Density of the Ear.*—The density of the spikelets on the rachis has been used by many observers as a character for differentiating the various kinds. Wheats are often referred to as lax, medium or dense according to the distance between the spikelets. These terms, however, are not very definite, and we have followed von

1 Howard, A. & G. L. C., *Jour. Agr. Science*, Vol. II, 1907, p. 278.
2 Biffen, R. H., *Jour. of Agr. Science*, Vol. II, 1907, p. 109.
3 Fruwirth, l. c.

Neergard[1] in expressing the density of the ear by a number (D) which gives the number of spikelets per 100 mm. of the rachis.

Most of the common wheats are very much alike as regards density. From the measurements of D in the Punjab 1908 crop they fall into two groups represented by densities of 20 or 24. This fact combined with the great variation in density produced by the conditions of growth in India has led us to reject density as a means of distinguishing the kinds in India. Differences in soil moisture and nutrition affect the length of the ear considerably, while the onset of the hot weather often cuts short the development of the later shoots, the ears of which are much shorter and denser than the earlier formed ears on the same plants. We have found that greater differences in density in ears of the same plant can be obtained than exist between different kinds of common wheat. Eriksson[2] has laid great stress on density in his classification of European wheats and in fact divides up his botanical varieties by means of this character. The conditions in India are such that his classification could not be usefully adopted.

(*c*) *Character of the spikelets and glumes.*—In one instance the shape of the spikelets and glumes has been used to help to separate two kinds very similar in most other respects. The ease with which the spikelets shed their grain is also an important character and one which is very constant for any particular kind. As a general rule in India, the beardless wheats shed their grain more readily than the bearded forms and are consequently not favourites with the ryots. Thin glumes generally go with easily shed grain while the thick glumed forms hold their grain much more strongly. An extreme case of a thick glumed wheat which holds the grain is to be seen in Indian Emmer.

The character of the keel of the outer glumes is of great importance. In macaroni wheats the keel is very pronounced right down to the base of the outer glumes, while in the dwarf and common

[1] von Neergard, Normal system för bedömande af axets morfologiska sammansättning hos vara sädesslag, *Allm. svenska Utsädesföreningens anberättelse för ar* 1887, s. 37.

[2] Eriksson, l. c. See also Fruwirth, Bd. IV, page 146.

wheats the keel is only pronounced in the upper portion and fades away or entirely disappears in the lower half. In Punjab type 9, however, the keel, although not so pronounced as in the macaroni wheats, is nevertheless distinctly represented in the lower part of the outer glume.

(*d*) *Erectness of the ear.*—The erectness of the ear is a character which we have found most useful in distinguishing in the field agricultural kinds which are very similar morphologically. In the arrangement of our Lyallpur plots all the wheats which, in the first selection in 1906, appeared to be either identical or else closely related were sown next to next. In some cases where a difference existed between two similar but not identical sorts, it was often easy to see by the position of the ears that the two kinds were different. In the one case the ears had a tendency to bend over while in the neighbouring plots the ears stood erect. Such differences in erectness were naturally accompanied by other differences in straw character and tone of colour of the chaff. It is a character which can only be used in the field and in plots which cover a certain amount of ground like that occupied by the produce of a single ear in the second season. It is not always possible to observe it in the first selection from a mixed plot.

9. Summary of botanical & field characters.

It will be convenient to deal with the above characters under two heads: (1) botanical or morphological: and (2) field or agricultural characters.

Botanical or morphological characters are those characters which remain constant with change of environment or season and which are inherited. They can be determined in the laboratory from properly developed specimens. These botanical characters are :—

1. Presence or absence of awns.
2. Felted or smooth chaff.
3. Colour of the chaff.
4. Colour of the grain.

5. Structure of the straw.
6. Character of the leaves.
7. Form or shape of the ear.
8. Character of the spikelets and glumes.

Field or agricultural characters are less conspicuous and cannot be distinguished in the laboratory or from individual plants. They can only be fully appreciated in pure cultures in the field grown side by side and under uniform conditions. The erectness of the ear, the tone of colour of the chaff and straw are field characters influenced less by season and environment than such agricultural characters as the strength and length of straw, earliness and lateness, the density of the spikelets and susceptibility to rust. All the above are characters of the greatest use and are to a very large extent inherited, but the latter group are liable to the effects of environment and season. How change of soil, moisture and locality affects them has already been dealt with and need not be repeated.

The consistency of the grain and the brightness of the sample are exceedingly variable even in the same locality, and we have not used these characters at all in separating sorts.

In considering the detailed classification of the wheats a difficulty is met with on account of the very different meanings attached to the various sub-divisions of the species. Such terms as variety, sub-variety, race, type, kind, sort are very seldom defined and where they are explained it is found that different writers use them in very different senses. The best discussion of the subject we have found is that given by Fruwirth.[1] He deals at considerable length and in detail with the development of the conception of varieties, and "Sorten" up to the present time.

We have followed Koernicke[2] as to the meaning of the term variety. By variety is understood those forms of a sub-species or

[1] Fruwirth, *Die Zuchtung der landwirtschaftlichen Kulturpflanzen*, Bd. 1, Zweite auflage, 1905.

[2] Koernicke, l. c.

species which can be differentiated in properly developed single individuals by definite, inherited and easily distinguishable characters, such as the presence or absence of the awns, smooth or felted chaff, colour of the glumes and grains. Our varieties are therefore the botanical units of the species and sub-species and represent the lowest limit to which wheats can be divided in the laboratory with precision. Each variety, however, may comprise several agriculturally distinct types. We have divided the varieties where necessary into types by means of the field characters, such as length and strength of straw, earliness or lateness, tone of colour of chaff and straw, erectness of the ear, and susceptibility to rust. The types represent the agricultural units of a variety in a similar manner as the varieties are the botanical units of the species or sub-species. The agricultural types are just as constant as the botanical varieties, but are not so readily distinguished except in the field. To determine the types it is necessary to grow them in pure culture for several years under uniform conditions. We have in our study of the Punjab wheats carried the classification down to the type. Our types are practically synonymous with the "Sorten" of Fruwirth and Koernicke. In more than one case the same botanical variety contained valuable and almost useless types. We have found it best to distinguish the types not by one character alone but by the sum of their field characters.

As regards the system of classification in the cultivated wheats, three have been proposed—those of Koernicke,[1] Eriksson[2] and Vilmorin.[3] It has been already pointed out that the system of Eriksson depends on the density of the spikelets and is unsuitable for use in India. Vilmorin has not sufficiently distinguished between the types, while Koernicke in *Die Arten and Varietäten des Getreides*, only considers the botanical varieties. Koernicke's classification has been extended by Werner[4] in *Die Sorten und der Anbau des Getreides*, but he has only

[1] Koernicke, l. c.
[2] Eriksson, l. c.
[3] Vilmorin, l. c.
[4] Werner, *Die Sorten und der Anbau des Getreides*, Berlin, 1885.

described the "Sorten" one after the other under Koernicke's varieties, and there is nothing to show how far the names really represent different types.

We have followed Koernicke as regards the varieties using his varietal names and have extended the classification down to the types.

In the following classification we have therefore used :—

1. As varietal characters :—
   - *a.* Presence or absence of awns.
   - *b.* Felted or smooth chaff.
   - *c.* Colour of chaff (red or white).
   - *d.* Colour of grain (red or white).
2. As agricultural type characters :—
   - *a.* Tone of colour of chaff.
   - *b.* Erectness of ears.
   - *c.* Characters of straw (length, strength and colour).
   - *d.* Earliness and lateness.
   - *e.* Susceptibility to rust.

IV.

CLASSIFICATION AND DESCRIPTION OF THE WHEATS OF THE PUNJAB.

The material from which our types were segregated consisted of 72 plots of wheat at Lyallpur (collected by the Director of Agriculture from all the districts of the province), and also a collection of the wheats grown by the cultivators of the Chenab colony. These plots were carefully searched in the field during the harvest of 1906, and all the constituents of each plot collected. These were then examined in the laboratory at Pusa and separated into botanical varieties. The same botanical variety was thus often found to occur in many plots.

The botanical varieties were sown at Lyallpur in 1906 as follows: the constituents of each variety found in the various plots were sown separately from single plants, and in 1907 these cultures were carefully examined both for vegetative characters at flowering time and also for further agricultural or field characters at harvest time. In this way it was found that in many cases the variety was made up of several types, in others there was only one type. The types were then described and the cultures repeated in 1907. In 1908, the types were finally determined in the field from a study of the comparatively large plots then available. Twenty-five different types were distinguished, the classification and description of which are given below. In many cases it was found that the types occur all over the province either in partly pure or very mixed culture under different names, and that many of the wheats cultivated in the new Chenab colonies were brought by the settlers from other parts of the province. Many of the wheats commonly grown are without doubt of a poor character and not very valuable for export pur-

poses. Others, on the other hand, including some of the rarities, are likely to be of considerable value:—

CLASSIFICATION OF THE PUNJAB WHEATS.

Triticum durum Desf. Macaroni wheats.

I. Glumes felted.

A. Glumes white, awns often black.

a. Grain white.

var. *melanopus* Al.

Type 1.

b. Grain red.

var. *africanum* Kcke.

Type 2.

II. Glumes smooth.

A. Glumes white, awns always white.

a. Grain white.

var. *leucurum* Al.

Type 3.

Triticum compactum Host. Dwarf wheats.

I. Ears bearded.

1. Glumes smooth.

A. Glumes red.

a. Grain red.

var. *erinaceum* Kcke.

Type 4.

II. Ears beardless.

1. Glumes felted.

A. Glumes white.

a. Grain white.

var. *linaza* Kcke.

Type 5.

2. Glumes smooth.
   A. Glumes white.
      a. Grain white.
         var. *Humboldti* Kcke.
         Type 7.
      b. Grain red.
         var. *Wernerianum* Kcke.
         Type 6.

TRITICUM VULGARE VILL. COMMON WHEATS.

I. Ears bearded.

1. Glumes felted.
   A. Glumes red.
      a. Grain red.
         var. *barbarossa* Al.
         Type 8.
   B. Glumes greyish white, awns black.
      a. Grain red.
         var. *fuliginosum* Al.
         Type 9.

2. Glumes smooth.
   A. Glumes red.
      a. Grain white.
         var. *erythroleucon* Kcke.

Type 10—Chaff dull light red, heads bend over when ripe, early, straw short and weak. D = 21.

Type 11—Chaff bright red, heads erect when ripe, late, straw tall and strong. D = 25.

Type 12—Chaff dull light red, with a somewhat bluish tone and with occasional blackening of the awns, chaff sometimes blackish also, heads bend over when ripe, grain easily shed, straw pink turning black on ripening, tall, of medium strength. D = 21.

      b. Grain red.

var. *ferrugineum* Al.

Type 13.

B. Glumes white.

a. Grain white.

var. *graecum* Kcke.

Type 16.

b. Grain red.

var. *erythrospermum* Kcke.

Type 14—Ears bend over when ripe, grain shed rather easily, early, straw weak, short, somewhat resistant to yellow rust. D = 23.

Type 15—Ears erect, less readily threshed than type 14, late, straw strong, tall, liable to yellow rust. D = 25.

II. Ears beardless.

1. Glumes felted.

A. Glumes red.

a. Grain white.

var. *Delfii* Kcke.

Type 17—Chaff with a bluish tinge, straw medium. D = 19.

Type 18—Chaff yellowish red, ears erect when ripe, straw stronger than 17, later in ripening. D = 26.

B. Glumes white.

a. Grain white.

var. *leucospermum* Kcke.

Type 19.

2. Glumes smooth.

A. Glumes red.

a. Grain white.

var. *alborubrum* Kcke.

Type 20—Chaff light yellowish red, ears more erect and later than in type 21, straw taller and stronger. D = 24.

Type 21—Chaff brownish red, dull, ears bend over when ripe, earlier than type 20, straw medium. D = 20.

b. Grain red.

var. *milturum* Al

Type 22—Sometimes slight bearding, chaff dark brownish red, shiny, grain dark red. D = 19.

Type 23—chaff dull yellowish red, grain easily shed, light red. D = 23.

B. Glumes white.

a. Grain white.

var. *albidum* Al.

Type 24—Spikelets blunt, outer glumes short and rounded, chaff white with a reddish border, ears bend over slightly, straw strong. D = 20.

Type 25—Spikelets pointed, outer glumes long and pointed, chaff yellowish white, shiny, ears erect, straw very strong. D = 20.

DESCRIPTION OF THE TYPES OF PUNJAB WHEAT.

Triticum durum Desf. Macaroni Wheats.

Ears flat, flowering glumes with long awns, outer glumes sharply keeled to the base, straw stiff and solid.

There are three varieties of Macaroni wheats found in the Punjab, var. *melanopus* Al. (type 1), var. *africanum* (type 2), var. *leucurum* Al. (type 3). Of these, the first is the most common and represents the so-called "Vadanak" wheat of the province. The other two were only found in very small quantities, especially type 3. Macaroni wheats on account of their large water requirements are generally only grown round wells and their cultivation is very limited. The flour is used mostly for confectionery. These wheats ripen late and are more attacked by birds than the ordinary wheats. This may be due to the stiff straw and ears on which it is possible even for heavy birds to perch and also to the fact that on account of their tall straw they range above all the other wheats. These wheats have broad long leaves smooth on the upper surface with hairs on the claws. Even when thinly sown they do not tiller much.

var. *melanopus* Al.

Type 1. Awns long, black but the black colour is lost very easily; chaff densely felted, white with a pinkish tinge, often spotted with mould fungi; grains long, amber, generally hard and flinty although occasionally mottled ones are found;[1] density varies with the rankness of growth;[2] straw tall, slender but stiff; somewhat liable to rust; ripens late.

This is the common macaroni of the Punjab and was found in the Wadanak of Zira, Wadanak of Sialkot, Wadanak of Batala, Wadanak Kalchingari of Montgomery, Wadanak of Amritsar, Dagar of P. D. Khan, Dagar of Wazirabad, Dagar of Shahpur, Pamman of Ferozepore, Dagar of Muzaffargarh, Dagar of Multan, Dagar of Montgomery and in the Wadanaks of Lyallpur, Ferozepore and Amritsar and the Palestine of Lahore.

var. *africanum* Kcke.

Type 2. Similar in most respects to type 1 but the ears taper to a point and are slightly longer; grain very dark red, hard on the whole, with a very few mottled grains; length of ear 84 mm.;[3] D = 28. This type is more liable to rust than type 1.

Type 2 was only met with as an impurity in Wadanak Kalchingari of Montgomery.

var. *leucurum* Al.

Type 3. Awns long, white with a reddish tinge; chaff smooth, shiny, white with a pinkish tinge due to the veins on the glumes being red; grain very long and thin, white, much lighter in colour than type 1, generally very hard and translucent, hardly a mottled

1 The descriptions of the consistency refer to the samples obtained in the harvest of 1908 when the types were grown in small plots next to each other.

2 Both the length of ear and the density vary very much in type 1. At first it seemed possible that there might be two types differing only in density but from the single ear culture we were unable to isolate two strains constant as regards density.

3 Length of ear & D were both measured in specimens from the harvest of 1908 and are the average of 20 typical ears. As explained in the earlier pages no great stress can be laid on these measurements. They are merely given as an indication of the value of these quantities.

grain to be found; length of ear 75 mm.; D = 22; straw good; ripens late; not so liable to rust as type 1.

Type 3 was only found as an impurity in the Wadanak of Lyallpur in very small quantity. The grains of this wheat are so long that in cleaning prior to grinding they would pass over standard sieves with the large impurities.

Triticum compactum Host.—Dwarf wheats.

Ears exceedingly dense and short, rarely over 5 cms. long, outer glumes keeled in the upper half and rounded in the lower half, straw very short and stiff, grains rounded.

There are four varieties of dwarf wheats grown in the Punjab. These wheats are drought-resisting and are generally grown on inundation moisture with little rain. They are also said to be good yielders and type 7 has a good reputation for bread making. Owing to the smallness of their grain they can however only be used for indigenous consumption and they are therefore being gradually replaced by common wheats. They agree with the common wheats in time of ripening and showed themselves exceedingly susceptible to early rust, *P. triticina* Eriks, when grown at Pusa, in fact they were almost destroyed by it. They are, however, fairly resistant to yellow rust. The ears are short and erect, the straw stiff, short (generally about 3′ 6″ or 4′), hollow throughout as in common wheats but much stouter.

Humphries[1] remarks that "types 4 and 7 are extraordinarily small in the berry, so small that millers would hesitate to buy them if they contained any small seeds because the machinery used for extracting the small seeds would take out simultaneously a very large proportion of the wheat berries themselves."

var. *erinaceum* Kcke.

Type 4. Ears bearded with short bristly spreading awns very irregular in length, awns red; chaff smooth and dark red; grain very small, round, rather a light dirty red in colour, very difficult to distinguish from a dark amber, hard on the whole with a few soft

1 See Appendix A.

grains; ear length 50 mm.; D = 38; straw shows no pink colour.

To this type belongs the Makkhi of Chiniot.

var. *linaza* Kcke.

Type 5. Ears beardless; chaff felted with short hairs, white with a pinkish tinge due to the pink colour of the edges and veins of the glumes; grain round, small but larger than in type 4, amber coloured, hard on the whole with a few soft and mottled grains; ear length 49 mm.; D = 38; straw pinkish, turning black or greyish pink on ripening.

This type was only met with in small quantity in the Makkawali of Dera Ghazi Khan.

var. *Wernerianum* Kcke.

Type 6. Ears beardless, but with occasional very slight bearding; chaff smooth, white with a pinkish tinge; grain round, about the same size as in type 5, a clean light red, all soft; ear length 44 mm; D = 39; straw has no pink colour.

This type was only found in small quantity in the Makini of Multan.

var. *Humboldti* Kcke.

Type 7. Ears beardless; chaff smooth, white with a pinkish tinge; grain round, about the same size as in type 5 but possibly a little smaller, amber coloured, consistency very variable, hard, soft and mottled grains found in about equal proportions; ear length 45 mm.; D = 41; straw pinkish, turning black on ripening.

This is the common dwarf wheat of the Punjab and was found in the Rodi of Shahpur, Rangrih or Ghiali of Kangra, Makini of Multan, Daudi of Muzaffargarh, Daudan of Multan, Makkawali of D. G. Khan and in Daudi of Multan.

Mr. A. C. Dobbs, of Lyallpur, found that this wheat was grown at Rawalpindi and that it was considered in that district as the best for bread-making.

TRITICUM VULGARE VILL.—COMMON WHEATS.

Eighteen of the 25 types of wheat found in the Punjab belong to this species and among them are found the wheats most commonly

grown. These 18 types belong to 11 botanical varieties and are equally divided into bearded and beardless, there being 9 types belonging to each class. Among the 18 varieties only 5 are felted but among these felted types are to be found some of the best wheats of the Punjab. The range in quality is very various, type 9, one of best being a good wheat fit for export, whereas some have a most inferior grain hardly worth growing for local consumption.

var. *barbarossa* Al.

Type 8. Ears bearded; awns red; chaff felted with short, rather sparse hairs, yellowish red; grain dark red, consistency variable, hard, soft and mottled grains found in about equal proportions; ear length 78 mm.; D = 24; straw good; ears erect and rather slender.

This type was found in the Lal Kasar-wali of Lyallpur in very small quantity.

var. *fuliginosum* Al.

Type 9. Ears bearded; awns stiff, stout, rather short, black but lose their colour very easily; glumes sharply keeled to the base; chaff densely felted with long hairs, the felting resembles very closely that found on the macaronis, chaff greyish white or yellowish white, pink at the edges, generally with black spots of *Cladosporium;* grain very dark red, on the whole hard with a few mottled grains, the shape resembling that of a common wheat; ear quadratic in section, somewhat club-shaped at the top, somewhat compact; ear length variable about 70 mm. on the average; D = 25; straw stiff, stout, hollow throughout; ears very erect.

This type was found in the Lal of Batala, Ratti of Montgomery and in the Lal Kale Kasar-wali of Lyallpur, it was also found in small quantity in the Lal Desi of Jhelum, Lal of Delhi, Pamman of Ferozepore, Dagar of Multan, Kunjhari of Muzaffargarh.

This wheat is one of the most interesting types found in the Punjab for although it must be classed as a common wheat, it appears to possess many of the characters of the macaronis. The felting resembles very closely that of the macaroni wheats and is quite different to that found on the other felted common wheats or on the felted dwarf wheat. The shape of the glumes with the keeling continued sharply to the base resembles that of macaronis. The hollow straw and the shape of the grain are, however, those of a common wheat. The shape of the ear with its compact sometimes club-shaped top, the stoutness of the straw and the stiff awns remind one of the dwarf wheats and it seems quite possible that this wheat, which is unique in India, may have arisen from a natural cross between a dwarf and macaroni wheat. This supposition is supported by the fact that we have found a dwarf wheat to be the female parent in some of the natural crosses found by us and described in the last part of this paper. At flowering time this wheat (type 9) appears to shed a vast amount of pollen and probably gives rise in this way to further natural crosses (see p. 61). It is interesting to note that this wheat is marked by Humphries as being the best of the 25 Punjab types submitted to him.

var. *erythroleucon* Kcke.

Type 10. Ears bearded; awns red; chaff smooth, dull light red; grain amber coloured, liable to sprout in the ear, consistency variable, hard, soft and mottled grains found in equal proportions; length of ear 82 mm.; D = 21; straw short and weak, ears bend over when ripe; early.

This type was found in the Safed of Moga, Mundi of Ludhiana, Jogia of Karnal.

Type 11. Ears bearded; awns red; chaff smooth, a more intense and brighter red than in type 10; grain amber coloured, liable to sprout in the ear, consistency variable but with a majority of soft grains; ears squarer and denser than in type 10, ear length 76 mm.; D = 25; straw tall and strong, ears stand erect; later than type 10.

This type was found in the Safed of Amritsar, Sohan of Chiniot, Kunjhari of D. G. Khan, Daudi of Lyallpur, and in the Jogia of Karnal.

Type 12.[1] Ears bearded; awns red with occasional blackening; chaff smooth, dull light red with a somewhat bluish tone, occasional blackening on the chaff; grain amber coloured, hard on the whole; ear length 86 mm.; D = 21; straw intermediate in strength between that of types 10 & 11, pink, turning black on ripening, tall; ears bend over when ripe; early; grain easily shed.

This type was found in the Rangrih of Palampur.

var. *ferrugineum* Al.

Type 13. Ears bearded; awns red; chaff smooth, shiny, yellowish or brownish red; grain red, intermediate in colour between the dark and light red grained types, rather small, consistency variable, about two-thirds being hard; ear length 96 mm.; D = 18; straw medium; ears fairly erect; rather late.

This type was found in the Lal Kasar-wali of Lyallpur. The hard red of Gujar Khan also belongs to this type, but ripened a little later than the Lal Kasar-wali. This difference may easily disappear after the hard red of Gujar Khan is acclimatised at Lyallpur.

var. *erythrospermum* Kcke.

Type 14. Ears bearded; awns pinkish yellow; chaff smooth, white with a reddish tinge when ripe; grain light red, hard and soft grains in about equal proportions; ear length 80 mm. D = 23; straw weak and short; ears bend over when ripe; early fairly rust-resistant; sheds its grain more easily than type 15.

This type was found in the Lal of Karnal, Lal of Sialkot, Lal of Attock, Lal Safed of Sirsa, Lal of Zira, Kasalu or Surkh of Ferozepore, Ratti or Lal of P. D. Khan, Lal of Ludhiana, Desi Surkh of Jullunder, Lal Desi of Jhelum, Lal of Rawalpindi, La of Delhi, Kunjhari of Muzaffargarh.

[1] We have found some difficulty in describing the differences between these three types (10, 11 and 12): they are best seen in the field.

Type 15. Ears bearded; awns pinkish yellow; chaff smooth, white with a reddish tinge when ripe; grain light red, consistency variable but the majority are soft grains; ear length 80 mm.; D = 25; straw tall and strong; ears erect when ripe; late; susceptible to rust; grains less easily shed than in type 14.

This type was found in the Ratti or Lal of P. D. Khan, Watni of Shahpur, Kunjhari of Multan.

Types 14 and 15 form the common red wheat of the Punjab. A glance at the names of the varieties will show that they are cultivated all over the province. They are very similar to, if not identical with, the common red wheats cultivated in the United Provinces. These two types are absolutely identical in the laboratory but quite different in the field.

var. *graecum* Kcke.

Type 16. Ears bearded; awns rather pinkish yellow; chaff smooth, white with pink edges and veins; grain white, rather small, on the whole soft but with some hard and mottled grains; ear length 78 mm.; D = 23; straw fairly strong.

This type was found in the Ghoni of Lahore, Safed of Ludhiana, Safed of Rohtak, Safed of Batala, Daudkhani of Dāsuya, Daudkhani of Delhi, Pori of Montgomery and in the Safed Kasar-wali of Lyallpur.

var. *Delfii* Kcke.

Type 17. Ear beardless; chaff felted with short, rather sparse hairs, red with a bluish tinge; grain amber coloured, consistency variable, hard, soft and mottled grains present in equal proportions; ear length 94 mm.; D = 19; straw medium.

This type was found in the Rodi of Attock, Ghoni of Gujrat, Ghoni of Sialkot, Khoni of Jhelum, Ghoni of Chiniot, Ghoni of Amritsar, Khoni of Batala, Mundli of Karnal, Mundli of Ludhiana, Safed of Lahore, Kanku of Palampur, Jhakrehun of Palampur, Safed Brij Sondha of Rohtak and in small quantity in the Rodi

of Muzaffargarh, Ghoni Lal, Ratti of Muzaffargarh, Desi of D. G. Khan, Suthra of Multan.

This is a very common wheat in the Punjab.

Type 18. Ears beardless; chaff felted with short, rather sparse hairs, yellowish red ; grain amber coloured, consistency variable, but the majority of the grains are soft; ear length 72 mm.; D = 26 ; ears squarer and denser than in type 17 ; straw stronger than in type 17; later in ripening.

This type was found in the Rodi of Muzaffargarh, Ghoni Lal, Ratti of Muzaffargarh, Desi of D. G. Khan, Suthra of Multan and in small quantity in the Ghoni of Chiniot, Ghoni of Amritsar, Jhakrehun of Palampur.

var. *leucospermum* Kcke.

Type 19. Ears beardless but occasional slight bearding met with; chaff felted with some short somewhat sparse hairs, white with pink veins or edges to the glumes; grain whiter than in 17, 18 and 21 but darker than 16 ; consistency variable but about three-quarters of the grains soft; ear length 74 mm.; D = 24; straw strong, pinkish, turning black on ripening.

This type was found only in very small quantity in the Buggi of Leiah at Lyallpur.

var. *alborubrum* Kcke.

Type 20. Ears beardless with occasional very slight bearding; chaff smooth, light yellowish red; grain amber coloured, rather large, consistency variable but about two-thirds of the grains soft; ear length 78 mm.; D = 24 ; straw taller and stronger, ears more erect and later in ripening than type 21; grain very easily shed.

This type was only found in the Ghoni of Amritsar.

Type 21. Ears beardless, with occasional very slight bearding; chaff smooth, brownish red, dull; grain amber coloured but somewhat whiter than 17, 18 and 20, consistency variable, about an equal amount of hard, soft and mottled grains ; ear length 90 mm. ;

D = 20; straw medium; ears bend over when ripe; earlier than type 20; grain very easily shed.

This type was found in the Kanku of Palampur and in small quantity in the Rodi of Attock, Ghoni of Gujrat, Ghoni of Sialkot, Khoni of Jhelum, Khoni of Batala, Mundli of Karnal, Mundli of Jullunder, Mundli of Ludhiana, Jhakrehun of Palampur, Ratti of Muzaffargarh, Kunjhari of Muzaffargarh, Kunjhari of Multan, Safed Ghoni and Ghoni Lal.

var. *milturum* Al.

Type 22. Ears beardless sometimes slightly bearded; chaff smooth, shining, dark brownish red; grain very dark red, consistency variable but on the whole the sample is hard; ear length 94 mm.; D = 19; straw medium but rather better than in type 23.

This type was found in small quantity in the Ghoni of Sialkot and in Safed Ghoni.

Type 23. Ears beardless; chaff smooth, dull, yellowish red; grain very light red, somewhat small, entirely soft; ear length 81 mm.; D = 23; straw medium.

This type was only found in the Ratti of Muzaffargarh.

var. *albidum* Al.

Type 24. Ears beardless; spikelets blunt; outer glumes short and rounded, chaff smooth, white with a reddish border; grain yellowish white, resembles 19, rather large, consistency variable but on the whole the sample is soft; ear length 93 mm.; D = 20; straw strong; ears bend over slightly.

This type was found in the Koni of Chakwal, Kunj of Muzaffargarh, Buggi of Leiah and Safed Ghoni.

Type 25. Ears beardless, often slightly bearded; spikelets pointed, outer glumes long and pointed; chaff smooth, yellowish white, shiny, with very slight reddish border; grain larger than in any other of the types of common wheat in the Punjab, greyish white of a different tone of colour to any of the other white wheats,

on the whole soft; ear length 100 mm.; D = 20; straw very strong; ears erect.

This type was found in Buggi of Leiah and Safed Ghoni.

These two types, 24 and 25, differ in appearance so much from all the other wheats of the Punjab and bear such a strong resemblance to the Australian wheats introduced into the province that we cannot help suspecting that they originally came from Australia.

V.

THE QUALITY OF INDIAN WHEAT.

There are two points to be taken into account when considering the quality of the wheats produced in a country like India. In order of importance they are, firstly, the needs of the local market and, secondly, the requirements of the export trade. It is commonly supposed that the classes of wheat best suited to the Indian and European markets are quite distinct. We shall endeavour to show in this section that such an idea is erroneous and that the wheats in greatest demand for local consumption and those preferred by the English millers are of the same general class, namely, hard and flinty wheats. We propose to put forward evidence, to show that the present cultivation of weak soft wheats like Muzaffarnagar white for export is a mistake and has been the means of lowering the status of Indian wheat in the English market and consequently has entailed the loss of large sums of money to the Indian producer.

The quality of a wheat for bread-making purposes depends chiefly on the consistency, colour, composition and milling characters of the grain and on the colour and baking value of the resulting flour. These matters will be dealt with in order.

1. Consistency.

In a previous section (p. 14) the subject of the consistency of the wheat grain from the systematic point of view has been considered and it has been shown that for purposes of classification this character varies to too great an extent with the environment to be of any value. From the milling point of view the consistency of the wheat grain is of the greatest importance and to some extent

determines the market value of a wheat. Millers like wheats of uniform consistency and on this account definite grades are maintained in the United States and Canada; and an inspection system has been built up for the purpose of maintaining these grades. As far as possible, hard and soft wheats are kept distinct and fall into the various hard or soft grades. It is in the conditioning or in the adjustment of moisture prior to grinding that the miller finds it an advantage to handle hard and soft wheats separately and where a mixture of hard and soft leads to trouble and loss. Consequently it is an advantage to export wheats uniform in consistency. Unfortunately, however, in India, wheats do not always come true to texture and we have found in the Chenab Colony of the Punjab, where wheat is grown under excessive Canal irrigation, there is a tendency towards the production of mottled grains—hard and soft in places—and to an unevenness in consistency. As has been pointed out above (p. 14), new wheats introduced into a district tend to develop the same consistency as that of the country wheats. Thus at Pusa, wheats tend to become hard and flinty. In some parts of the United Provinces, for example the Muzaffarnagar district, uniform soft grades appear to be developed.

To bring out this point a pure sample of Muzaffarnagar white was grown in 1908 in three localities—at Lyallpur in the Punjab, at Muzaffarnagar in the United Provinces and at Pusa in North Behar. In consistency, the resulting harvest was quite distinct. At Muzaffarnagar, the sample was uniformly soft white, at Lyallpur there was a fair proportion of flinty and semi-flinty grains, while the general tint was a duller white. At Pusa, the colour was amber and the majority of the grains were hard or semi-hard. As will be seen below, both the composition and baking values of these three samples were notably different, and the Pusa grown specimen was considerably the best. It is one of the future problems in Indian wheat investigations to see how far consistency can be regulated by cultivation and irrigation and in what tracts wheats uniform in consistency can be produced.

2. Colour.

The change, now almost complete in Great Britain, from the old system of grinding wheat under mill-stones to that of the modern roller mill has led to quite different views on the part of millers as to the importance of the colour of the grain. Under mill-stones more of the skin of the grain found its way into the flour and consequently red wheats did not yield flour of such good colour as white wheats.[1] With roller mills, however, the separation of the skin is almost complete and the disadvantages of red wheats no longer exist to any appreciable extent. That this is so is evident when it is remembered that Canadian Fife wheat which is one of the strongest wheats exported to England is a hard red wheat but realises prices about the highest in the market.

While it is not possible to judge the milling value of a wheat from the colour, yet it is safe to state that, as a rule, the hard wheats with a somewhat dark tint have the highest nitrogen content and give the best results in the bakehouse. Very light red and white wheats often give weak flours.

3. Composition.

Although a great deal of work has been done on the chemical composition of wheat and of wheat flour, yet no accurate relation has hitherto been found between the chemical composition and the breadmaking value of wheat. The only determination of any value is the nitrogen content which is usually determined by Kjeldahl's method and which, when multiplied by the factor 5·7, gives the percentage of proteids. Hall[2] found that *as a rule* the higher the nitrogen content the stronger the flour, but there are exceptions as some wheats high in nitrogen give very weak flours.

The range in total nitrogen and proteid content in wheat is very great. Thus Soule and Vanatter[3] in America give 8·1 & 13·6 as the limits of the proteid percentage in the American wheats

1 Maurizio, *Getreide. Mehl und Brot*, Berlin, 1903, p. 112.

2 Hall, A. D., *Journal of the Board of Agriculture* (England), Vol. XI, No. 6.

3 Soule and Vanatter, *Bull. IV, Agr. Expt. Sta. Tennessee*, 1903.

investigated by them. Far higher values, however, can be obtained, some of the stronger wheats of Hungary, Roumania and South Russia often containing 20 per cent. or more of gluten.

According to Fruwirth,[1] climate in Europe has a considerable effect on the composition of wheat. "Dryness and poverty of soil clearly increase the gluten content. Besides this it must be remembered that according to Wollny high summer temperature and low rainfall in Hungary, Roumania and South Russia favour nitrogen content and flintiness; cooler damper climates, on the other hand, favour starch production and flouriness. In agreement with this the nitrogen content of wheat in Europe in general diminishes from South to North and from East to West. Thus the gluten content in South Russia, Roumania and Turkey is 20 per cent. or over, in Germany and France 10 to 15 per cent., and in England seldom more than 10 per cent."

Tschermak[2] quotes several cases of change of composition when European wheats were removed from one country to another.

During the season 1907-08 in India we obtained results with Muzaffarnagar white similar to those discussed by Tschermak. Samples of this wheat grown at Lyallpur, Muzaffarnagar and Pusa gave very different results on analysis and also differed considerably in bread-making value.

Composition and baking value of Muzaffarnagar wheat grown at three stations in 1908.—

	% Nitrogen. (Leather).	Order in Baking value (Humphries).
1. Grown at Pusa	1·86	Fifth.
2. Grown at Lyallpur .	1·50	Eighth.
3. Grown at Muzaffarnagar ...	1·38	Ninth.

The nitrogen content of the 25 Punjab types has been determined on the 1908 crop by Leather as follows :—

[1] Fruwirth, l. c.

[2] Tschermak, l. c.

Nitrogen content of Punjab wheats.

Type No.	1	2	3	4	5	6	7	8	9
Percentage of Nitrogen ...	1·75	2·61	2·2	2·14	1·78	1·62	1·71	1·52	2·01

Type No.	10	11	12	13	14	15	16	17	18
Percentage of Nitrogen ...	1·40	1·34	1·50	1·57	1·37	1·43	1·39	1·42	1·39

Type No.	19	20	21	22	23	24	25
Percentage of Nitrogen ...	1·35	1·43	1·45	1·38	1·35	1·37	1·62

It will be seen that with one exception the common wheats, Types 8 to 25, all give nitrogen values below 2 per cent. and are therefore low in gluten. The macaroni wheats, types 1 to 3, and the dwarf wheats, types 4 to 7, on the whole, are distinctly higher in nitrogen than the common wheats.

4. Milling and baking tests.

A considerable amount of information as to the probable usefulness of a wheat can be given by an expert miller who is accustomed to buy wheats on hand samples and to grind them into flour. Accordingly, the types of Punjab wheat were submitted to Mr. Humphries of Weybridge and his report is given in Appendix A. From this it will be seen that types 8 and 9, both red wheats, were considered to be the best. A still more reliable opinion, however, can be obtained from an actual milling and baking test, if conducted by an expert provided with a suitable mill and baking facilities. This was done for us this year by Mr. Humphries with ten samples, each about 60 lbs. in weight, from various parts of the Indo-Gangetic plain.

Six of these wheats were obtained from Lyallpur, one from Gujar Khan, one from Muzaffarnagar, and two from Pusa:—

Description and composition of ten samples of Indian wheat tested in England in 1908.

No.	Name.	Grown at	Character of grain.	Percentage of Nitrogen (Leather).
1	Pusa No. 6	Pusa ...	Hard white	2·52
2	Lal Kasarwala.	Lyallpur ...	Hard white	Not determined.
3	Punjab type 9	Lyallpur	Hard red	2·01
4	Gujar Khan	Gujar Khan ...	Hard red ...	1·76
5	Muzaffarnag a r white.	Pusa ..	Semi-soft white	1·86
6	Punjab type 16.	Lyallpur ..	Soft white ...	1·39
7	Punjab type 14.	Lyallpur ...	Soft red ...	1·37
8	Muzaffarnag a r white.	Lyallpur	Soft white	1·45
9	Muzaffarnag a r white.	Mazaffarnagar	Soft white ...	1·34
10	Australian 27...	Lyallpur ...	Soft white ...	Not determined.

Numbers 1, 3, 5, 6, 7 and 8 were pure cultures grown by us at Pusa and Lyallpur. Nos. 2, 4, 9 and 10 were obtained in ear from cultivators' fields, all ears not true to type being picked out before threshing.

The report on the milling and baking qualities of these wheats is given below :—

REPORT BY A. E. HUMPHRIES, ESQ., PAST PRESIDENT OF THE INCORPORATED NATIONAL ASSOCIATION OF BRITISH AND IRISH MILLERS AND CHAIRMAN OF THE HOME-GROWN WHEAT COMMITTEE OF THE INCORPORATED NATIONAL ASSOCIATION OF BRITISH AND IRISH MILLERS ON THE TEN SAMPLES OF INDIAN WHEAT SENT FROM PUSA IN 1908.

I duly received, *viâ* Calcutta or Kurrachee, the ten sample lots of various wheats grown in India, upon which the Agricultural Department of the Indian Government wished me to report, and in accordance with the arrangement arrived at with you, I have cleaned, conditioned, milled and baked each lot separately and have done each operation in duplicate.

I have regarded the whole matter from the standpoint of a British miller and am accustomed to buy Indian wheats on a commercial basis for the manufacture of flour to be used in England.

The methods of milling and baking followed are those which I have used in making a great number of similar tests for the Home-grown Wheat Committee of the National Association of British and Irish Millers.

The ten samples were designated as follows :—

Red wheats.—Gujar Khan.
Punjab Type 9.
Punjab Type 14.

White wheats.—Pusa 6 grown at Pusa.
Lal Kasar Wala.
Muzaffarnagar grown at Lyallpur.
" " " Muzaffarnagar.
" " " Pusa.
Australian 27 Lyallpur.
Punjab Type 16.

I do not think that the colour of the husk need be or is likely to be of great importance. British millers are guided in their preferences principally by the quality and quantity of flour which Indian wheats would yield, but if on other points a red wheat and a white wheat were equal, the preference would be given to the white wheat.

Each of the ten samples was noteworthily free from dirt and extraneous matter. The arrangements arrived at by the joint action of shippers, the leading British Corn Trade Association and the Association of British and Irish Millers have brought about a great improvement on this point in the recent shipments of Indian wheat, and if it be possible to ship wheat as "clean" as the ten samples I have received, the relative value of Indian wheats would be still further enhanced.

As part of the process of cleaning wheat by washing, and to prevent as far as possible the pulverizing of the husk in grinding and so secure a better separation of husk from kernel, it is the custom of British Millers to "condition" their wheats.

The most important point in the conditioning is the adjustment of the moistures immediately prior to grinding, so that wheats with

high moistures would be dried and wheats with low natural moistures would be damped. Of course, this means that practically all Indian wheats would be damped and that the driest would be worth more to the miller than those with higher moistures. Incidentally, I should like to mention the belief entertained here that some parcels of Indian wheat are artificially damped before shipment. Any such action is unwise from the Indian point of view. It is risky as regards the effect on quality, it seems silly to pay railway and ocean freight on water, and any gain so obtained on the first few transactions would be much more than lost in the long run, because all British Millers of good standing know quite well the moistures of the wheats they receive, that point enters into their calculations as to the relative values of wheats, and they are likely to base their calculations to the detriment of sellers on the highest percentage of water the wheats they buy will contain.

The ten samples were all in the best of condition on arrival.

When water is added in the process of cleaning and conditioning, it affects the kernel as well as the husk, and all varieties of wheat are not affected alike. Some remain "free grinding," that is to say, the kernel, when pulverized, makes lively granular flour which can be separated from husk with a minimum of trouble to the miller; others become "woolly" in texture, the flour is less granular and the separations in the mill are made with difficulty.

The ten samples show a striking difference in this respect. For free grinding Pusa 6 is very good indeed, Australian 27 poor. The Muzaffarnagars are also poor in this respect, and of the three the one grown at Lyallpur is the worst. The five sorts not specifically mentioned in this connection are good as regards this characteristic.

There are very great differences in the hue of the flours from the ten samples. The three Muzaffarnagars all yield flour very white in hue. Of the three, that grown at Muzaffarnagar is the whitest, that grown at Pusa is substantially the same, whilst the Lyallpur lot of this variety has a comparatively dingy hue. I think this is associated with the "woolliness" I have mentioned, because to get a commercially complete separation of husk from

kernel more force in grinding has to be used and more of the husk accordingly gets pulverised in the grinding. The Australian 27 yields also a white flour. Punjab Type 9 yields a bright but very yellow flour. Gujar Khan one that is yellow in slightly lesser degree. Pusa 6 is as regards colour in a class by itself, for its very lively granular flour is neither white of chalky hue nor yellow, but a greyish white, which I associate with Canadian Fife wheat. Of the other three sorts not specifically mentioned in this paragraph, Punjab Type 16 yields flour of very good appearance as regards hue, medium between the chalky white of the Muzaffarnagar and the yellows of the Punjab Type 9 and Gujar Khan. A large number of British millers use artificial bleaching. In their hands the two last named would give good results as to colour. In some parts of England and in Ireland flour of chalky white hue is required, and for those purposes the sorts yielding such flour might be preferred, but my own preference as to colour would be Pusa 6 or Lal Kasar Wala, and this, I think, would be the verdict of most English millers.

There are great differences between the ten as regards strength, by which I mean the capacity for making large shapely loaves. On this point Pusa 6 is pre-eminent. The loaves are not only larger, but whereas those from all the other flours have the appearance typical of Indian varieties, those from Pusa 6 have a quite different and a superior crust and general appearance. Gujar Khan, Punjab Type 9 and Lal Kasar Wala are not far behind so far as size of loaf is concerned. Of the three Muzaffarnagars, the Pusa lot is distinctly the best, the Muzaffarnagar distinctly the worst, the Lyallpur lot occupies the middle position. The Punjab Types 14 and 16 and Australian 27, are only poor on this point.

As regards the stability of dough, in baking all are good. Pusa 6 is the nearest approach to the toughness which is associated with Canadian or American Spring Wheats, but that is not to be compared with those sorts, nor should I expect to find any wheats behaving in that way unless with great summer heat a high summer rainfall be associated.

In summarizing the foregoing, I unhesitatingly express the opinion that Pusa 6 is the best, and I can quite as unhesitatingly say, I do not like Australian 27 or Muzaffarnagar grown at Muzaffarnagar. There is a growing inclination amongst grain merchants to mix their wheats so as to reduce the number of grades in which they deal. No particular harm would be done if they mixed as follows :—

A. Muzaffarnagar grown at Muzaffarnagar.
,, ,, ,, Lyallpur.
,, ,, ,, Pusa.
27 Australian.
B. Lal Kasar Wala.
Punjab Type 16.
C. Punjab Type 9.
Gujar Khan.

Punjab Type 14 might be grouped with C, but would be better handled separately. Pusa 6 might be grouped with B, but would make most money if sold by itself, on its own sample or reputation. Group A should not be mixed with either B or C, nor should any individual of the group A be mixed with any member of the group B or C. If group B were mixed with group C, no particular harm would be done, but they are better apart.

Different millers may have different opinions about the same wheat, and as indicated herein some sorts may have special values in different localities, but as a miller trading in the London district, I should put the ten in the following order having regard to all the points mentioned—

1. Pusa 6.
2. Lal Kasar Wala.
3. Punjab Type 9.
4. Gujar Khan.
5. Muzaffarnagar grown at Pusa.
6. Punjab Type 16.
7. ,, ,, 14.
8. Muzaffarnagar grown at Lyallpur.

9. Muzaffarnagar grown at Muzaffarnagar.
10. Australian 27.

I find great difficulty in answering your question as to the relative money values of these ten Indian wheats and Canadian and American grades. Canada and the U. S. A. grow some poor weak wheats, and I would certainly pay as high or even a higher price for any of the ten as I would for Canadian Winters, or for the wheats grown on the Pacific slope of the U. S. A., or for most of the U. S. A. winter wheat shipped as they are with all their uncertainties as to grading, but these Indians are quite different to Canadian or U. S. A. Spring wheats, and are not comparable with them. So long as the world grows so much more weak wheat than strong wheat, and so long as millers are compelled to supply flours of good or great strength, wheats capable of yielding flour from which tough, stable doughs and big loaves can be made will command a large premium.

Some authorities measure strength by the number of loaves a given quantity of flour will produce, but a reliable opinion cannot be formed on this point on small lots such as you sent me. It is, however, quite safe to say that the better of your ten would rank high on this point. The relative value of Indian wheats has already gone up a great deal as a result of improved cleaning and greater reliability in quality, and if wheats as good in intrinsic quality, as well grown, as clean and as dry as say the first six on my last list are shipped here from India, the growers can rely on a still further increase in their relative value in competition with the wheats of the world.

ALBERT E. HUMPHRIES.

It will be seen from this report that the four best wheats from a milling and baking point of view are hard wheats. Further, these varieties are also hardy wheats, good yielders and with good straw and in two cases at least with considerable resistance to rust. The soft wheats such as Muzaffarnagar white are, comparatively speaking, inferior wheats.

The extension of the cultivation of soft white wheats in India for export to Europe dates from the year 1883, when a report by Messrs. MacDougall Bros. of London, on the milling and baking tests of four parcels of Indian wheat was published.[1] These wheats were as follows :—

(1) Soft white from the Meerut and Muzaffarnagar districts.

(2) Soft red from the Meerut district.

(3) Hard red from the Banda district of Bundelkhand.

(4) Hard white from Khandesh in Bombay.

These wheats were milled in London by the then ordinary process of grinding under mill stones and also by the Hungarian or roller system which was at that time a novelty in Great Britain. Comparisons were made with English, American, Australian, Russian and Egyptian sorts both in the mill and subsequently in the bakehouse.

It is clear from the report that the hard red and hard white wheats were macaroni wheats and not bread wheats and are not usually exported to England for baking purposes. The soft white wheat from Muzaffarnagar was considered to be the best of the four, and, from that time, its cultivation and that of similar weak soft white sorts has been considerably advocated for export purposes. That this has been a great mistake will be clear when it is remembered that at the time these tests were made, most of the wheats used in England were ground under mill stones for which hard wheats and especially hard red wheats were not very suitable. Since that time, however, the modern roller mills have entirely replaced the old mill stones in England. In these mills the hard flinty strong wheats of Russia and North America can be handled with ease, and red wheats are almost as good as white sorts. The use of these flinty wheats in turn set up a new standard of flour strength and they were used almost entirely to mix with the weak soft wheats which make up the larger portion of the world's production. Strong

1 This report is published in *The Wheat Production and Trade of India*, Calcutta, 1883.

wheats are at a premium in England. In the last 25 years, therefore, the conditions of the wheat trade in England have been revolutionised both as regards method and material. No corresponding change has been made in the wheats exported from India, only weak wheats are exported and therefore it is not surprising to find that there is a belief in England that India can only produce weak wheats. Thus Humphries and Biffen[1] in a recent paper state "the fact that India, Australia and California export wheats no stronger than our own makes it clear that abundance of sunshine does not necessarily result in the production of strong wheat." This is no doubt true of the soft Indian wheats now exported, but we do not think it is by any means true of all Indian wheats.

That strong wheats are grown in India seems to have been first discovered by Farrer[2] in 1899, who, in a letter to the Revenue Secretary to the Government of India, dated August 9th of that year, stated:—"On account of the high strength of the flour they produce, I take the liberty of recommending to you for extensive propagation the first two varieties of the three mentioned above, for I regard them as the best of all the Indian varieties which thus far have come under my notice. Your Indian varieties appear to vary greatly in the quality of flour strength."

Many enquiries in the villages in the Indo-Gangetic plain have elicited the information that for his own use the cultivator prefers hard wheats, often hard reds. These he considers to be greatly superior in food value to the soft wheats grown largely for export. The people fully understand the value of the chewing test and for their own consumption prefer those varieties which yield a sticky mass in the mouth after mastication. It will be seen from the letter from Messrs. Ralli Brothers (Appendix B) that if hard wheats were put on the market, there would be little difficulty in obtaining a premium for them.

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[1] Humphries and Biffen, *Journal of Agricultural Science*, Vol. II, 1907.

[2] Farrer in the Proceedings of the Government of India (Revenue and Agricultural Department, Nos. 1—4, October 1899). These wheats came from Etawah and Muzaffarnagar in the United Provinces. The Muzaffarnagar wheat was not Muzaffarnagar white, but a beardless variety.

It will be evident from the above that the demands of the local and export trade are the same and both prefer hard strong wheats. The growth of weak soft white sorts for export is therefore a mistake. When the English millers realise that India can produce much stronger wheats than those at present exported, the growth of weak soft wheats will be given up and the hardier, more easily cultivated flinty wheats will take their place.[1]

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[1] Yielding power will naturally have to be taken into account as well as grain quality and hardiness. In recommending new wheats to the cultivators it will be necessary to select those which combine hardiness and high grain quality with good yielding power.

VI.

NATURAL CROSS-FERTILISATION IN INDIA.

In general, the flowers of all the species and varieties of wheat are self-fertilised, pollination taking place before the extrusion of the stamens. The details of the wheat flower are well illustrated by Hays,[1] while there are good detailed accounts of the opening of the glumes and of the extension of the anthers both by Fruwirth[2] and by Hays. Koernicke[3] observes that the stigmas themselves sometimes protrude their fine points, when the glumes open at the top for the liberation of the stamens, and remain in the open even after the closing of the glumes.

Instances of natural cross-fertilisation in the field are not common. Some observers even go to the length of stating that natural crossing does not take place. Thus De Vries[4] states "wheat, barley and oats are self-fertile and do not mix in the field through cross-pollination." Garton[5] from his experiments in England comes to a similar conclusion. He states :—

"The first step was to ascertain whether natural cross-fertilisation actually existed in the cereals. At the time it was an accepted doctrine that all agricultural plants were open to artificial cross-fertilisation, but there were no definite or reliable records to prove that such was the case. On the settling of this question depended the possibility of the work attempted. The method adopted was as follows :—

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[1] Hays, *Bull.* 29, *U. S. Dept. of Agriculture, Div. of Veg. Phy. & Path.*, 1901.

[2] Fruwirth, l. c., Bd. 4, 1907.

[3] Koernicke, l. c.

[4] De Vries, *Species and Varieties, their Origin by Mutation.* 2nd Ed., 1906, p. 98.

[5] Garton, *Journal of the Farmers Club*, 1900, p. 47.

A suitable number of heads of wheat were selected in a field crop, and the immature anthers were carefully removed from about half a dozen florets on each head, the remaining florets being left intact. The ovules in the florets from which the anthers had been removed had thus every opportunity to become fertilised by pollen either from the surrounding florets left intact upon the same heads or by pollen from outside sources. Not one single embryo was developed in the florets thus treated. This was considered sufficient evidence to justify the belief that natural cross-fertilisation did not exist."

Biffen[1] who grew over 200 varieties of wheat at Cambridge in England, says they are autogamous with rare exceptions, and he states "I have never met with a case of natural cross-fertilisation."

Darwin in *Animals and Plants under Domestication* states: "With respect to the natural crossing of distinct varieties, the evidence is conflicting, but preponderates against its frequent occurrence."

These observations, it will be observed, refer to comparatively damp climates, and it is no doubt true that in England natural crossing in wheats is exceedingly rare. We have so far only found three cases in the records, the first of which is quoted in the *Journal of the Board of Agriculture* of November 1905:—"It is an extremely rare thing to find a single case of natural cross-fertilisation. The possibility of such an operation being caused by bees is so extremely remote that it can be said to have no existence. Because of its rarity it may be well to put on record that in the course of the Committee's work one case or perhaps two have been met with.[2] A farmer, Mr. R. Cook, of Box near Bath, planted in 1902 a field with a mixture of Square-head's Master and Essex rough chaff—two sorts of wheat which from the breeder's point of view possess marked differences. When the crop matured, he came across a plant with nine ears of particularly robust growth. He propagated their contents (560 grains) and has supplied the

1 Biffen, l. c.

2 The Committee referred to is the Home-grown Wheat Committee in England who for some years past have been working to improve the milling qualities of English wheats.

Committee with an ear of the progeny which certainly seems to indicate that a natural cross did take place. Extremely rare though such cases of natural cross-fertilisation may be, it is not at all difficult to cross-breed wheat artificially.''

Two more cases of natural crossing in England in which Red Fife was the female parent have been observed at Chertsey in 1906.[1]

Although natural crosses are very rare in the damp climate of England, it by no means follows that such occurrences are equally rare in other wheat-growing countries. In drier and more sunny climates, such as that of the continent of Europe and some of the wheat-growing districts of North America, it is quite possible that natural crossing is much more common. A perusal of the literature shows that this supposition is amply confirmed. Thus in Jersey, LeCouteur[2] found that a red-felted wheat gave rise to felted red, smooth red, felted white, and smooth white plants. Another case of natural crossing was noticed by this observer in a Kentish felted wheat which gave rise to both smooth and felted progeny. Koernicke at Popplesdorf records several cases of natural crossing in *Die Arten und Varietäten des Getreides* published in 1885. Thus on page 31 he states :—'' It will be seen that wheat is arranged for self-fertilisation, but that cross-fertilisation is not impossible. That the latter occurs in the field was proved by me by undoubted crosses which I obtained in the garden and from which I grew some peculiar forms.'' On page 49, in describing the varieties of *T. compactum*, Host., Koernicke states that this group more than any other is disposed to cross in the field. Thus his varieties 25, *rufulum*, Kcke.; 26, *creticum* Mazzucato ; 29, *crassiceps* Kcke.; 30, *rubrum* Kcke.; 37, *sericeum*, Al.; 38, *albiceps* Kcke.; 39, *rubriceps* Kcke.; 40, *echinodes* Kcke. ; were obtained from natural crosses. Further, on page 62, when discussing the varieties of *T. durum* Desf., he states that one of the difficulties in

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[1] Report of the Home-grown Wheat Committee for the cereal year 1907.

[2] LeCouteur, *The Varieties, Properties and Classification of Wheat*, 2nd Ed., Jersey, 1872, p. 132.

dividing the varieties lies in the fact that in the south there are many more intermediate forms to be found than is the case with the German wheats. He considers this is probably due to the fact that in certain countries the sowings are extraordinarily mixed—wheats from Valencia gave on sowing a large number of varieties. In such cases Koernicke considered that it is easier for crosses to occur and the limits of the groups to be lost.

Fruwirth[1] brings together most of the recorded examples of natural crossing in wheat. The possibility of cross-fertilisation is supposed to have been proved for *T. sativum*, Vill., by an experiment of Rimpau in which 59 per cent. of castrated flowers freely growing in a wheat field set seed and by a similar experiment of von Liebenberg's in which 20 per cent. of flowers in the same manner set seed. As mentioned above, Garton in a similar experiment in England obtained no setting. Rimpau observed the occurrence of spontaneous bastards when different kinds were grown next to next. He cultivated 60 kinds of *T. vulgare* for 15 years and found 17 cases in which one could assume spontaneous crossing. Hansen at Lyngby and Nilsson at Svalöf are of opinion that in warm good weather forms cross with each other which are generally considered only to be self-fertilised, and that crossing between common wheats and spelts occurs under such circum stances. Fruwirth states that at Hohenheim he also noticed similar results and also crossing between forms of *T. sativum* and *spelta*.

In the United States, Carleton[2] considers that natural crossing sometimes occurs, and states "In a majority of the instances above described the circumstances too are such that one cannot escape the thought that the abnormal heads found in the fields were the results of natural crosses." In Canada, Saunders[3] has described a case of spontaneous crossing in the field between Red Fife (female) and Rio Grande (male).

[1] Fruwirth, l. c.

[2] Carleton, *Bull.* 24, *U. S. Department of Agriculture, Div. of Veg. Phy. & Path.*, 1900

[3] Saunders, *Bull.* 57, *Canadian Dept. of Agr.*, Oct. 1907.

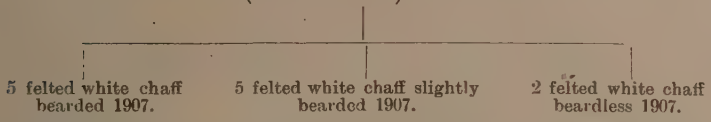
As it appeared probable that natural crossing occasionally takes place in warm countries, we have paid considerable attention to this point in India. In the pure culture plots at Pusa, many hundreds in number, during the last three years no cases of natural crossing have so far been discovered.

At Lyallpur, however, the results were quite different. Of the single-ear cultures, sown in 1906, four proved to be natural crosses. Three of these ears were collected on the Lyallpur Farm in May 1906, one was found in the collection of U. P. wheats from Saharanpur sent to us by Mr. H. M. Leake. We had no suspicion of any of these wheats being natural hybrids when they were sown, but considered they were rare types of wheat in cultivation.

In the plot of Safed Ghoni (a smooth white beardless wheat) at Lyallpur in 1906, two white felted, slightly bearded, red grained plants were noticed. These were sown from single ears in 1906, and in 1907 both gave rise to mixed offspring. The first, labelled P 145 A, gave rise to felted white chaff plants with red grains. Five plants were bearded, five were slightly bearded and two were beardless. In 1908 they split up still further.

P 145 A.

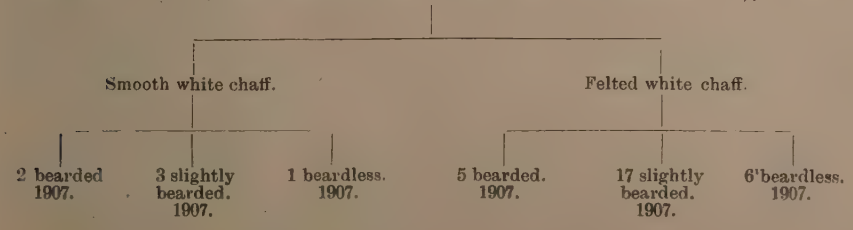
FELTED WHITE CHAFF, SLIGHTLY BEARDED. (PARENT EAR) 1906.



The other plant, P 146 A, also split up into bearded and beardless smooth and felted in 1907 and still further in 1908 :—

P 146 A.

WHITE CHAFF, FELTED, SLIGHTLY BEARDED, (PARENT EAR), 1906.



The beardless ear obtained from Saharunpur in 1906 (U. P. 158) gave rise to bearded and beardless in 1907 and split up still further in 1908. As the seed from which this ear was raised was sent from Cawnpore to Saharunpur, the crossing must have taken place at Cawnpore.

U. P. 158.

Smooth white chaff beardless (parent ear) 1906.

- 16 bearded smooth white chaff 1907.
- 14 slightly bearded smooth white 1907.

The fourth case of a natural cross found at Lyallpur in 1906 was in the plots of *T. compactum*. In Type 5 one of the felted beardless ears gave rise in 1907 to red-felted plants differing very much in density.

P5

Felted beardless 1906.

- 5 red felted beardless lax ..
  - white chaff felted ... lax / dense
  - red chaff felted ... lax / dense
- 5 red felted beardless dense ...
  - white chaff felted ... lax / dense
  - red chaff felted ... lax / dense
- 1 red felted beardless very dense ... (compactum type) 1907.
  - all dense felted ... red chaff / white chaff 1908.

In the harvest of 1907 at Lyallpur a slightly bearded smooth red chaff lax plant, not at all like a compactum, was observed in one of the dwarf wheat plots. This was sown separately in 1907, and in 1908 gave rise to 12 bearded and 11 beardless plants. They could also be divided up into lax and dense and into red and white chaff. In the present year (1908) in 42 of the 108 plots grown from the produce of single ears sown in 1906, we observed stray plants, often more than one in a plot. In many cases these were red or white chaff, felted, bearded, red grained plants, and most of them appear to be first generation of a cross between type 9 (Lal Kale Kasarwala) and the type in which they were found. These must have arisen either from natural crossing in 1907 or from stray seeds (either left in the soil from a previous crop or brought accidentally by ants, birds or in the irrigation water). As they are different in appearance from any known wheat at Lyallpur, and as natural crossing has already been proved by us to occur in the Punjab, we consider it exceedingly probable that these stray plants are natural crosses in the F_1 generation. Upwards of 100 of these supposed natural crosses will be sown this year and the results will be published in a subsequent paper. We are inclined to believe that in the Punjab in good years natural crossing is exceedingly frequent, especially when one of the kinds sown is type 9. In 1907 it was observed that the glumes of this sort open to a very wide extent when the anthers are ripe and liberate a vast amount of pollen into the air. As our plots were surrounded by a belt of this wheat on all sides, there were abundant opportunities for its pollen distribution. The season at flowering time was very dry and sunshine was abundant. Our artificial crosses made at this period at Lyallpur gave nearly 100 per cent. of fertilised grains. There is no doubt, therefore, that the season was a favourable one for natural crossing to take place. In conclusion, our opinion so far is that in the Punjab natural crossing is possible to such an extent that great care will have to be taken to keep the sorts pure and that plots grown next to each other must be very carefully rogued every year. At Pusa where, as a rule, the air is much damper at flowering time, natural crossing in the field seems to be very rare

APPENDIX A.

From A. E. Humphries, Esq., Weybridge, to the Imperial Economic Botanist, dated Weybridge, July 13th, 1908.

I duly received your letters of May 21st and 28th, and the 25 small samples of wheat have since come to hand. None of the ten large sample lots for milling and baking tests has yet arrived, but, in accordance with your request, I have examined the 25 small samples without waiting for the larger ones, and send you herewith my opinion as a British miller upon them.

When I speak of strength, I mean "a flour capacity for making big shapely loaves." Its capacity for making a large number of loaves from a given quantity of flour is in my view another matter upon which nobody can safely express an opinion by merely looking at samples. Of the many points upon which a miller bases his estimate of value in buying wheats, strength is the one to which pre-eminent importance is attached on almost all our United Kingdom markets. The very strong wheats of the world appear to be grown in countries where great heat is accompanied by a substantial or large summer rainfall, and as yet I have not come across any Indian wheat, which, on its own merits, in other words, when it is used for bread-making by itself, would come into our category of very strong wheat. I shall watch with very great interest any attempts you make to produce such wheats, especially if you experiment with Fife, but, in the meantime and particularly for my immediate purpose, I shall base my estimate of the commercial value of your wheats principally on their relative strength and the whiteness of the flour which they would yield under our modern conditions of milling. In this connection, I should like to point out that there is no invariable connection between the quality of the flour produced from the kernel of the wheat berry and the colour of the skin. A red skin does not necessarily indicate strength, nor does a white one necessarily indicate weakness, and sometimes the flour from red wheat is much whiter than the flour from white wheat. I have also to take into account how the wheats you have sent me would suit the methods of cleaning and milling in common use here. For instance, among your dwarf wheats are two (Nos. 7 & 4) which are extraordinarily small in the berry, so small that millers would hesitate to buy them if they contained any small seeds, because the machinery used for extracting the small seeds would take out

simultaneously a very large proportion of the wheat berries themselves. For that reason and having regard to the practical certainty of getting some small seeds into the bulks grown under commercial conditions, I would not recommend the growth of wheats 7 & 4, nor even of Nos. 5 & 6 unless there is some other characteristic, of which I know nothing, to strongly recommend them.

In recent years, a considerably increased quantity of Durum (Macaroni) wheats have been sold on British markets for ultimate use in bread-making, although as the alternative name implies their original or better use is for the manufacture of macaroni. Their great and inherent hardness is very different to the apparent hardness of your ordinary wheats, in which the hardness is due to mere absence of moisture, and in the estimation of millers making flour for bread-making purposes, Durum wheats are now, and are likely to be, at any rate for many years to come, worth much less money than your ordinary wheats. In all wheats, and especially in Durums, uniformity of texture is a most important desideratum. Millers in preparing their wheats for milling (the separation of husk from kernel) seek to get all wheats in their mixture into one uniform condition and with that object prepare some wheats very differently to others, before the blending of the various sorts is made. From this it would be obvious that growers or dealers in grain should, so far as possible, aim at exporting grain as uniform in texture as possible. This remark applies to your ordinary wheats as well, and affects my judgment on your samples. The principle of a remark I made concerning your dwarf wheats applies also to your Durums, but in another way. Our mills are fitted with elaborate systems of sifting machines in which the wheats pass through perforations in the sifting medium and large impurities pass over them. Of course, if millers found any additional commercial value for other reasons in very long berried wheats and could get a sufficiently large and regular supply, they would make the necessary changes in machinery, but such wheat as your No. 3 would pass over standard sieves into or with the large impurities, and in this case also, I would not recommend the export to the United Kingdom of such wheats for flour milling purposes, unless there be some strong recommendation, the existence of which I do not now suspect.

I note with much interest the cleanness of your samples, that is to say, their freedom from dirt, barley, seeds, and other extraneous matter. When I was President of the National Association of British and Irish Millers, I attended conferences of shippers, merchants and millers called to deal with the grave abuses which had been introduced into the Indian wheat trade, whereby, so we learned, such impurities were deliberately added to wheat with the object of obtaining for the sellers a greater monetary return. As a result of the arrangements arising out of those conferences, a great improvement has been brought about, but I would like to take this opportunity of remarking that if Indian wheats could be bought here regularly as clean and good as your samples, British millers would pay better prices than they do for them. Manitoban wheats fetch higher prices

on our markets than the corresponding grades of United States wheat because buyers believe they are more likely to get good deliveries of the former than of the latter, and Indian growers and dealers should realise that any action of theirs whereby confidence in the regularity of good deliveries is injured or destroyed, must in the long run do them much more harm than any temporary gain they may get.

Complying with your request to arrange the 25 samples in their order of merit, I set them out as follows:—

"Common wheats": Red:

9.
8.
22.
13.
14.
15.
23.

"Common" white wheats:

12.
10.
21.
17.
18.
20.
24.
19.
25.
16.
11.

In my opinion there is no difference in money value between those I have bracketed together. In case you would like me to put all the "Common wheats" in order of merit without making the distinction as to their colour, I set them out as follows:—

9 Red.
8 Red.
12 White.
10 White.
21 White.
17 White.
22 Red.
13 Red.
18 White.
20 White.
24 White.
19 White.
25 White.
16 White.
14 Red.
15 Red.
11 White.
23 Red.

Durums:—1, 3, 2. As we do not make macaroni in the United Kingdom, I think either of these would realise less money than any of the Common Wheats.

APPENDIX B.

From A. E. Anastasiades, Esq., Manager of Messrs. Ralli Brothers' Agency, Lyallpur, to the Imperial Economic Botanist, Pusa, dated Lyallpur, 12th May, 1906.

Wheat.—With reference to the conversation you had with the undersigned, our Karachi Principals write to us as follows :—

"The reason why we pay a better price for soft white wheat is that Great Britain and the North Continent, which take the bulk of Karachi wheat, generally prefer soft wheats.

"However, if purely hard wheat were produced in the Punjab in sufficiently large quantities to make it a merchantable description, and if the quality kept its characteristics from year to year and could be relied on to be matched at any time, an outlet for it could readily be found and possibly such wheat would command a premium.

"At present, purely hard wheat without an admixture of soft grain, reaches the Punjab markets in such small quantities that we are precluded from buying it on its own merits, and it has to be mixed in the so-called soft descriptions."